USAFSAM-TR-88-21R

MEDICAL MANAGEMENT OF COMBAT LASER EYE INJURIES

Robert P. Green, Jr., Colonel, USAF, MC, FS
Robert M. Cartledge, Lieutenant Colonel, USAF, BSC
Frank E. Cheney, Major, USAF, BSC
Arthur R. Menendez, Ph.D.

October 1988 (Revised December 1990)

Final Report for Period October 1986 - October 1988

USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301

NOTICES

This final report was submitted by personnel of the Ophthalmology Branch, Clinical Sciences Division, and the Vulnerability Assessment Branch, Radiation Sciences Division, USAF School of Aerospace Medicine, Human Systems Division, Air Force Systems Command, Brooks Air Force Base, Texas, under job order 7755-24-02.

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder or any other person or corporation, or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

Robert P. Green MD

ROBERT P. GREEN, JR., Col, USAF, MC
Project Scientist

James R. Hickman Jr.

JAMES R. HICKMAN, JR., Col, USAF, MC
Supervisor

George Schwender MD

GEORGE E. SCHWENDER, Colonel, USAF, MC, CFS
Commander

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): USAFSAM-TR-88-21R	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: USAF School of Aerospace Medicine; 6b. OFFICE SYMBOL (If applicable): USAFSAM/NGO	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code): Human Systems Division (AFSC) Brooks AFB TX 78235-5301	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: USAF School of Aerospace Medicine; 8b. OFFICE SYMBOL (If applicable): USAFSAM/NGO	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code): Human Systems Division (AFSC) Brooks AFB TX 78235-5301	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 62202F; PROJECT NO. 7755; TASK NO. 24; WORK UNIT ACCESSION NO. 02

11. TITLE (Include Security Classification)

Medical Management of Combat Laser Eye Injuries

12. PERSONAL AUTHOR(S)

Green, Robert P., Jr., Cartledge, Robert M.; Cheney, Frank E; Menendez, Arthur R.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 86/10 TO 88/10	1988, October (Revised 1990 December)	34

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Combat injuries; Eye injuries; Flashblindness; Lasers; Laser injuries; Medical management of injuries
06	05		
06	07		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A medical management report for the treatment of Combat Laser Eye Injuries was written to aid medical personnel in handling patients with suspected laser exposures. Background information on lasers, symptoms, diagnostic tests, clinical findings, treatment recommendations, and return to duty and evacuation criteria are discussed. In addition, the issue of eye protection is considered. The rapid growth of laser science and engineering has resulted in an increased use of lasers by the military. It is likely that in future engagements lasers will be used directly against our forces, and their effects on the health and mission performance of our aircrews are of particular concern. Since the optics of the eye can increase the retinal irradiance by a factor of 100,000 times over that which is incident at the cornea, the retina is especially vulnerable. Laser range finders and target designators are used in military operations, and energy inputs from these and other potential laser sources are sufficient to produce significant eye injury at distances of 1 km or more. Glare and flashblindness, which are temporary visual effects caused by visible lasers, are present

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Robert P. Green, Jr., Col, USAF, MC	22b. TELEPHONE (Include Area Code): 512-536-3241; 22c. OFFICE SYMBOL: USAFSAM/NGO

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. ABSTRACT (Continued)

for laser energies considerably below the damage threshold and can, therefore, interfere with mission performance at a considerably longer range. Aircrews protected by windscreens and canopies are primarily at risk from near infrared and visible lasers, while other personnel, such as air base ground defense forces, are additionally at risk from ultraviolet and far infrared lasers. Patients' symptoms from laser exposure will vary depending upon the power and wavelength of the laser, the structure of the eye affected, how close the exposure was to the visual axis, and the extent of the temporary or permanent effects on visual structures. Since it is probable that most medical personnel in the field have never previously dealt with a patient who has had a laser exposure, a report which provides background information on lasers and guidance on handling these patients has been written.

PREFACE

Purpose and Scope

This technical report provides basic information on laser injuries. The treatment and management procedures described herein are for use by USAF medical personnel. For additional information on lasers and peacetime medical laser procedures, the reader should consult AFOSH Standard 161-10, recent messages from HQ USAF/SGP, a joint USN/USAF laser training videotape ("Lasers in Military Operations," Part I), and the handbook ("Operational Hazards of Military Lasers: A Guide for Medical Personnel"), which contains a slide briefing ("Lasers and Aircrews: A Flying Safety Kit for Flight Surgeons"). Both the videotape and handbook are available from HQ AAVS, Norton AFB CA 92409.

Availability of Report

This technical report was prepared by the Ophthalmology (NGO) and Vulnerability Assessment (RZV) Branches of the USAF School of Aerospace Medicine (USAFSAM), Brooks AFB TX 78235-5301. It reflects the current thought of this organization and conforms to USAF policy. Additional copies may be ordered from the National Technical Information Service, 5285 Port Royal Road, Springfield VA 22161-2103. MAJCOMs are authorized to reproduce this technical report for wider distribution within their command. Questions and comments may be directed to the USAFSAM/NGO (AUTOVON 240-3258) or USAFSAM/RZV (AUTOVON 240-3622), Brooks AFB TX 78235-5301.

ACKNOWLEDGMENTS

The authors acknowledge the efforts of many individuals who provided technical review of the document: Ralph G. Allen, Ph.D., Donald N. Farrer, Ph.D., Col William Gibbons, Col H. Michael Lambert, David Sliney, M.S., Denise Varner, Ph.D., CAPT John A. Wolfe, and the staff of the Vulnerability Assessment Branch. In addition, we thank Mrs Julie Yochum, who tirelessly served as our secretary, and TSgt Mary Jo Austin, who immeasurably supported our needs for graphics and photography.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

Tables

Figures

MEDICAL MANAGEMENT OF COMBAT LASER EYE INJURIES

INTRODUCTION

A laser (light amplification by stimulated emission of radiation) is a device that emits an intense narrow beam of light at discrete wavelengths which range from the near-ultraviolet (invisible to the eye) through the color spectrum (visible) and into the far-infrared spectrum (also invisible). The rapid growth of laser science and engineering has resulted in the increased use of lasers by the military. Currently, laser range-finders and target designators are used in military operations by ground personnel, tanks, aircraft, ships, and anti-aircraft batteries. They are also used to simulate "live fire" in force exercises, where accidental injury to the eye may occur. It is likely that in future engagements lasers will be used directly against our forces, and their effects on the health and mission performance of our aircrews will be of particular concern. Laser energy outputs are sufficient to produce significant eye injury even at distances of a kilometer or more. Currently, aircrews protected by windscreens and canopies are at risk from near-infrared and visible lasers, while other personnel, such as air base ground defense forces, are additionally at risk from ultraviolet and far-infrared lasers. The injury effects of laser exposure, as well as the diagnosis, treatment, return to duty, and evacuation of injured personnel, will be addressed in this report. In addition, the issue of eye protection will be considered.

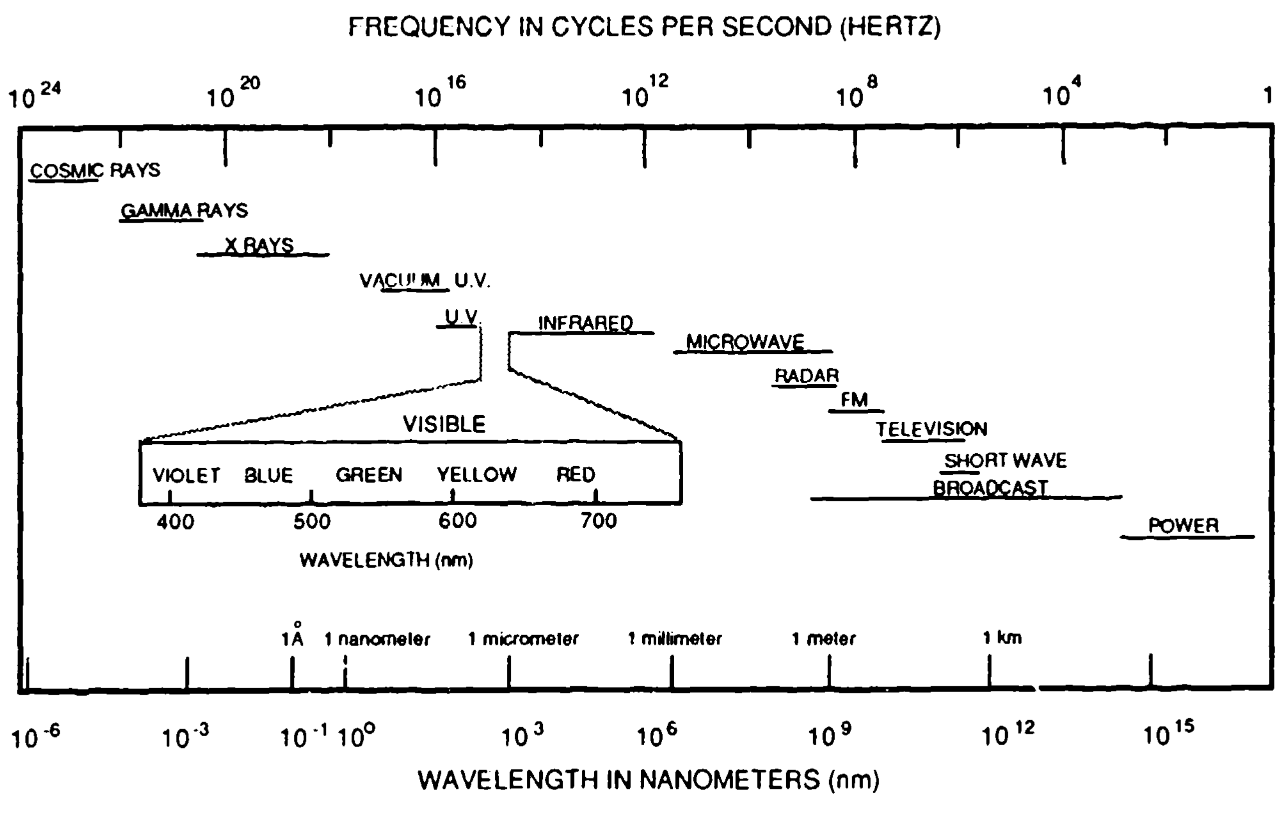

Figure 1. The radiant energy (electromagnetic) spectrum. (Adapted from McKinley, 1947).

PRINCIPLES OF LASER ENERGY

A laser produces a narrow, highly collimated beam of coherent (in phase) light which travels at 300,000 km per second, the speed of light. As distance from the laser source increases, the narrow beam will gradually diverge to a larger diameter. This beam can vary in wavelength throughout the electromagnetic spectrum (Fig. 1) and can be visible or invisible. Typically, laser wavelengths (often measured in nanometers - nm) are grouped into four major categories: ultraviolet (UV), 200-400 nm; visible, 400-760 nm; near-infrared (near-IR), 760-1400 nm; far-infrared (far-IR), 1400-10^6 nm. The characteristics of typical commercial lasers are delineated in Table 1.

TABLE 1. PRINCIPAL CHARACTERISTICS OF COMMON LASERS

Waveband	Wavelength (Nanometers)	Lasing Medium	Perceived Hue	Typical Operation
UV	325	Helium-Cadmium	N/A	CW
UV	337	Nitrogen	N/A	Pulsed
UV	351	Argon	N/A	CW
Visible	441.6	Helium-Cadmium	Reddish-Blue	CW
Visible	458	Argon	Blue	CW
Visible	468	Krypton	Blue	CW
Visible	488	Argon	Blue-Green	CW
Visible	511	Copper Vapor	Green	Pulsed
Visible	514.5	Argon	Green	CW
Visible	530	Doubled Nd:Glass	Yellowish-Green	Pulsed
Visible	532	Doubled Nd:YAG	Yellowish-Green	Pulsed
Visible	568	Krypton	Yellow	CW
Visible	632.8	Helium-Neon	Red	CW
Visible	647	Krypton	Red	CW
Visible	694.3	Ruby	Red	Pulsed
Visible	755	Alexandrite	Red	Pulsed
Near-IR	905	Gallium-Arsenide	N/A	Pulsed
Near-IR	1060	Nd:Glass	N/A	Pulsed
Near-IR	1064	Nd:YAG	N/A	Pulsed
Far-IR	10,600	Carbon Dioxide	N/A	CW, Pulsed

Note: In some cases, the perceived hues are also characterized by their secondary hue; for example, helium-cadmium is mostly blue with a reddish tinge. The alexandrite laser is tunable across some of the visible and near-IR wavelengths. Argon and krypton lasers can emit multiple, discrete wavelengths simultaneously. If the fundamental frequencies of Neodymium:Glass (Nd:Glass) and Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) wavelengths are doubled, their wavelengths become visible.

Lasers emit energy continuously (continuous wave - CW) or in short bursts (pulsed). The number of pulses that a laser emits within a given duration is the pulse repetition frequency (PRF). Confusion can result because CW lasers can appear to be pulsed, if their beam is "chopped," and pulsed lasers can appear to be CW lasers, if their PRF is too high for the eye to perceive the separate pulses (greater than 60 to 90 Hz). In addition, certain pulsed lasers can emit all of their energy compressed into time periods as brief as billionths of a second (nanoseconds - ns) or less. Some lasers, such as argon or krypton, can emit several discrete wavelengths simultaneously, although frequently the laser is adjusted to emit one wavelength at a time.

The radiant power output of a laser at a given instant can be stated in watts, as with any light source. However, while the radiant output of CW lasers is usually given in watts, that of pulsed lasers is usually given in joules per pulse. A watt unit (W) is equal to an energy of one joule (J) per second, where a joule is defined as the energy required to raise the temperature of 1 cc of water by 0.239° C. A laser, unlike an ordinary incandescent light source, has a very small beam divergence and, thus, can direct most of its radiant power, over very small areas even at great distances. A measure of this radiant power, at a position in space, is called irradiance and has the units of watts per unit area (e.g. W/cm^2), while a measure of radiant energy, at a position in space, is called the radiant exposure and has the units of joules per unit area (e.g. J/cm^2). The radiant exposure of a laser is equal to its irradiance multiplied by the duration of time (in seconds) that irradiance is present at the position in question.

Laser light is gathered and focused by the eye across a 2-7 mm pupil to a retinal image about 5-30 μm in diameter. This focusing can increase the retinal irradiance by a factor of 100,000 over that which is incident at the cornea. Thus, a relatively low-output laser can produce serious eye injury simply because the eye focuses the beam and, thus, increases the retinal irradiance. The use of light-gathering and magnifying optical instruments, such as binoculars, and other optical sighting devices increases the danger from exposures because they collect more of the laser light and further increase the ocular irradiance.

ANATOMY AND FUNCTION OF THE EYE (Fig. 2)

The wall of the eye is a sphere composed of three layers: a tough outer connective tissue shell (cornea--sclera); a fragile inner neurosensory layer (retina), and an intermediate vascular-connective tissue layer (iris, ciliary body, and choroid). The anterior cavity of the eye is filled by the aqueous humor, a watery fluid, and the posterior cavity by the vitreous humor, a gelatinous fluid. The crystalline lens with its suspensory ligaments is situated between the aqueous and the vitreous humors.

The cornea and lens are the focusing elements of the eye, while the retina is the imaging element. In particular, the posterior pole which includes the fovea and foveola is the most important retinal structure and provides for 20/20 vision. This area of the retina is depicted in Figure 3. The photoreceptor cells, which are buried deep in the retina, absorb light, convert it to electrical signals, and transmit the visual message to the brain via axons which leave the eye as the optic nerve.

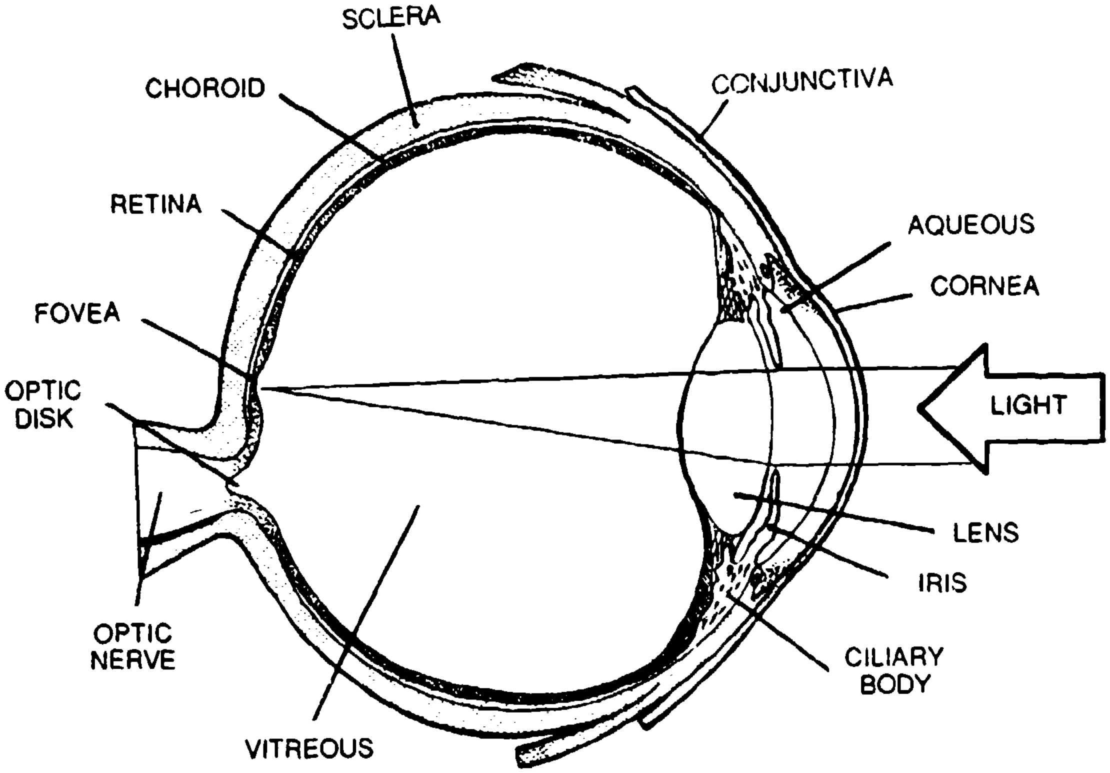

Figure 2. Anatomy of the eye. (Horizontal cross section).

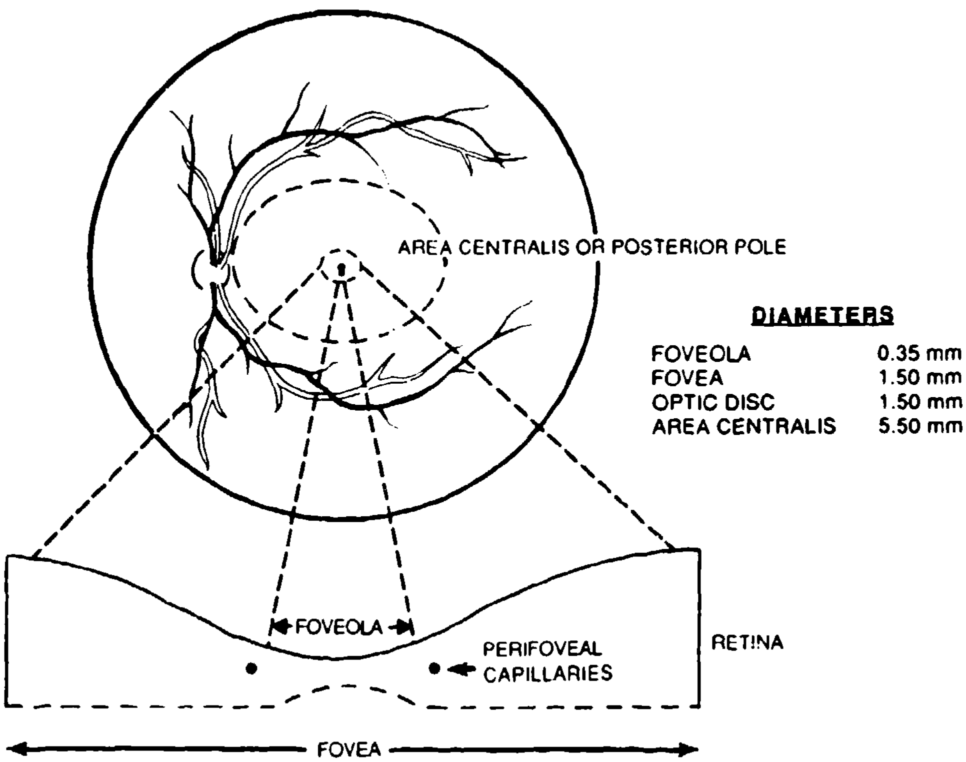

Figure 3. Anatomy of the posterior pole. (Adapted from Orth et al., 1977).

BIOLOGICAL EFFECTS

Absorption of Light

The microscopic anatomy and the presence of pigments or chromophores in ocular tissues determine whether the tissue in question will absorb or transmit light. The cornea and lens will absorb most of the light in the ultraviolet region (wavelengths shorter than 400 nm) because of the presence of certain proteins and nucleic acids. The cornea and lens are transparent to light in the visible (400-760 nm) and near-infrared (760-1400 nm) portions of the spectrum. Melanin, the major ocular pigment, is black and absorbs all wavelengths of light in the visible and near-infrared spectra. It occurs throughout the iris, ciliary body, and choroid, as well as in the retinal pigment epithelium, a layer of neuroepithelium between the sensory retina and choroid. Xanthophyll, yellow in color, absorbs preferentially in the blue portion of the visible spectrum (<500 nm). This pigment lies chiefly in the cells of the retina in the central (20/20) region of the posterior pole. Lipofucsin, an orange pigment, absorbs maximally in the blue-green portion (520 nm). Lipofucsin pigment is found in the retinal pigment epithelium. Blood absorbs preferentially in the green portion of the visible spectrum (530 nm). The absorption of light in the far-infrared portion of the spectrum, beyond 1400 nm, is related to the absorption characteristics of water which is considered a chromophore for infrared radiation.

The absorption of light by the eye and skin can also be described in terms of laser wavelength categories:

1. Ultraviolet. Laser radiation in this spectrum (below 400 nm) is primarily absorbed in the anterior segment of the eye by the cornea and lens, as well as by the skin. Some near ultraviolet light (315-340 nm) will, however, reach the retina.

2. Visible. Laser radiation in this spectrum (400-760 nm) is absorbed primarily within the retina by the photoreceptors, pigment epithelium, and choroid, as well as by the skin. The longer wavelengths (red) are absorbed more deeply in the retinal/choroidal tissue than the shorter wavelengths (blue).

3. Infrared. Absorption of laser energy in this spectrum (above 760 nm) occurs in two areas of the eye, as well as the skin. Laser energy in the near-infrared spectrum (<1400 nm) is absorbed by the retina and choroid, whereas laser energy closer to the far end of the infrared spectrum (1400-10^6 nm) is absorbed by the cornea. A transition zone exists, from 1200 to 1400 nm, where retina, cornea, and lens are all at risk.

Damage Mechanisms

The amount of damage is, in general, proportional to the amount of laser energy the tissue absorbs and will be dependent upon the wavelength of the laser light, exposure duration, pulse width, repetition rate, and irradiance. There are three primary mechanisms of laser damage: actinic; thermal; and mechanical. Actinic insults generate photochemical processes and are more prevalent with UV and shorter visible wavelengths. Examples include UV corneal burns and sunburns of the skin. The injury mechanism of most low-power visible and IR continuous wave lasers is one of thermal photocoagulation, i.e., superficial and deep corneal burns and retinal burns. High-power CW and pulsed lasers produce both thermal burns and mechanical tissue disruption. Figure 4 delineates the energy wavelengths and the adverse effects of each, along with the depth of skin penetration.

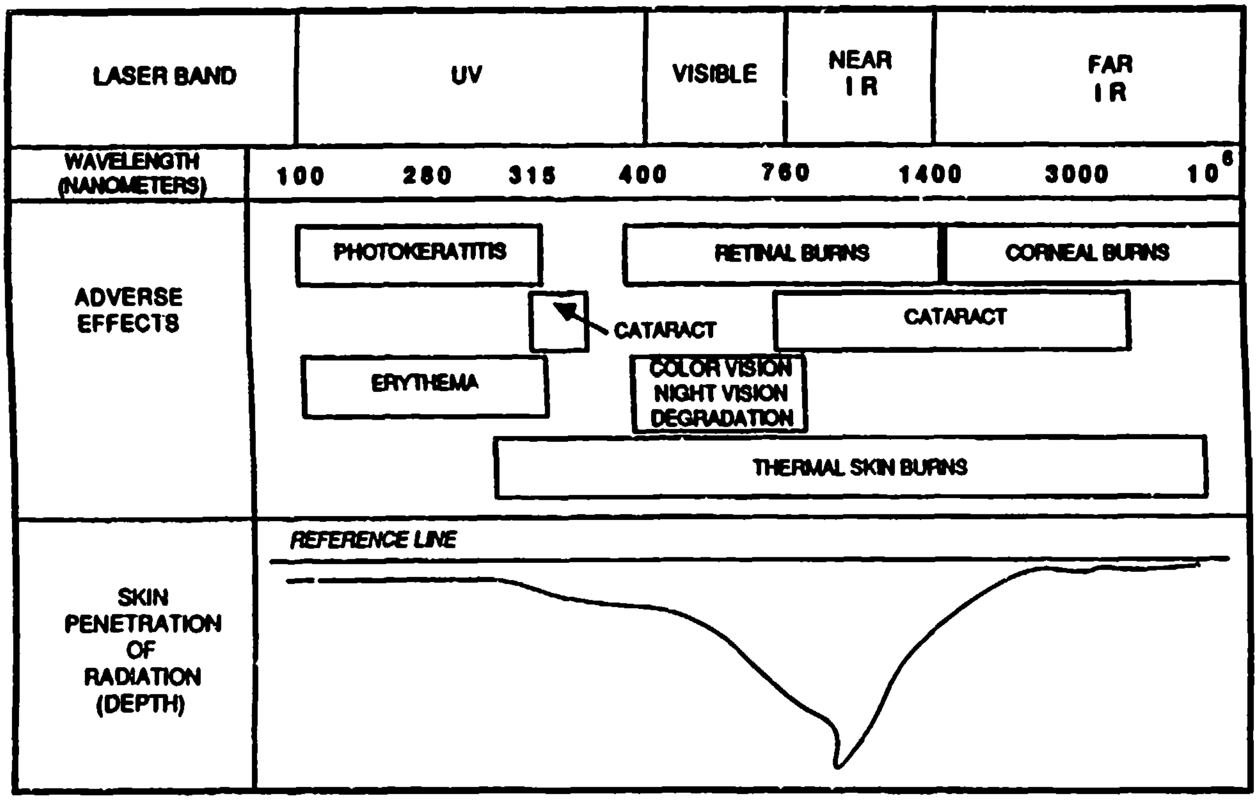

Figure 4. Adverse effects of lasers. (Adapted from Sliney and Wolbarsht, 1980).

Description of Potential Damage

Cornea

The effect of ultraviolet radiation on the cornea is to produce epithelial injury, a condition that can be painful and visually handicapping. At lower powers, this injury is primarily due to a photochemical reaction. A latency period of hours may exist between the time of exposure and the development of the corneal pathology. Minimal corneal lesions should heal within a few days, but meanwhile they could produce a decrement in visual performance.

Far-infrared radiation is also mainly absorbed by the cornea, producing immediate burns at all corneal layers. An infrared laser can produce a lesion which results in permanent scarring of the cornea. If the energy is sufficiently high, the cornea can be perforated; this perforation may lead to loss of the eye.

Retina and Choroid

The neurosensory retina is transparent to most wavelengths of visible light. However, laser energy in the visible range can produce inner retinal damage, although this is mainly secondary to the much greater absorption and destruction that takes place in the deeper and more pigmented tissue, the retinal pigment epithelium.

When the retinal pigment epithelium absorbs sufficient laser light energy, local thermal coagulation of adjacent photoreceptors and other structures of the retina also occurs. The surrounding retina will also be affected by edema. These processes result in a scotoma (blind spot) which varies in size depending upon the extent of the retinal damage. Acute (<24 hours old) argon laser burns of the human retina outside the posterior pole are shown in Figure 5. Note the dense white coagulated centers with the surrounding less dense edematous areas. Older argon laser burns of the retina usually have characteristic pigmentary changes and no longer appear completely white. Such lesions are shown in Figure 6. Figure 7 illustrates an acute retinal burn and two retinal/choroidal hemorrhages, one contained and one not contained by the inner limiting membrane of the retina, which were produced by a Nd:YAG laser. Vision may not be disturbed significantly by small retinal burns away from the fovea.

Visible and near-infrared lasers of sufficient power can produce hemorrhage in the choroid, a very vascular tissue, and disruption of the overlying retina. The visual loss from this hemorrhage may be quite severe. The blood can collect beneath the photoreceptor layer of the retina, disturbing its contact with the retinal pigment epithelium (detachment). This subretinal hemorrhage can result in the death of the photoreceptor cells and a scotoma that is much larger than the thermal burn or mechanical disruption. The blood may also move into the vitreous of the eye through the disrupted retina, where it may obstruct the passage of light through the ocular media. If extensive or centrally located, such hemorrhages can produce a significant loss of vision. Blood in the vitreous is absorbed very slowly, but it is cleared eventually in most cases. The visual impairment remains as long as the blood persists. Vision may improve to normal with resorption of the blood. Blood that has persisted for several months may be removed by a complicated surgical technique called vitrectomy. This procedure may also return vision to a "near normal" level, if the underlying retinal/choroidal damage does not involve the fovea.

The mechanical shock effect of laser pulses can also "wrinkle" the retina, resulting in malfunctioning of the photoreceptors and distortion of the perceived visual field corresponding to that area of the retina.

Laser injury to the retina may also damage the conducting fibers (axons) of the retina, producing a visual field defect peripheral to the site of injury. Laser damage to the retinal/choroidal areas can produce brief, albeit significant, pain.

Skin Damage

The threshold for skin burns is similar to that of the cornea for ultraviolet and far-infrared wavelengths. For visible and near-infrared wavelengths, the skin's threshold is much higher than that for the retina, since the concentrating power of the eye is not a factor.

Figure 5. Acute argon laser burns of the human retina.

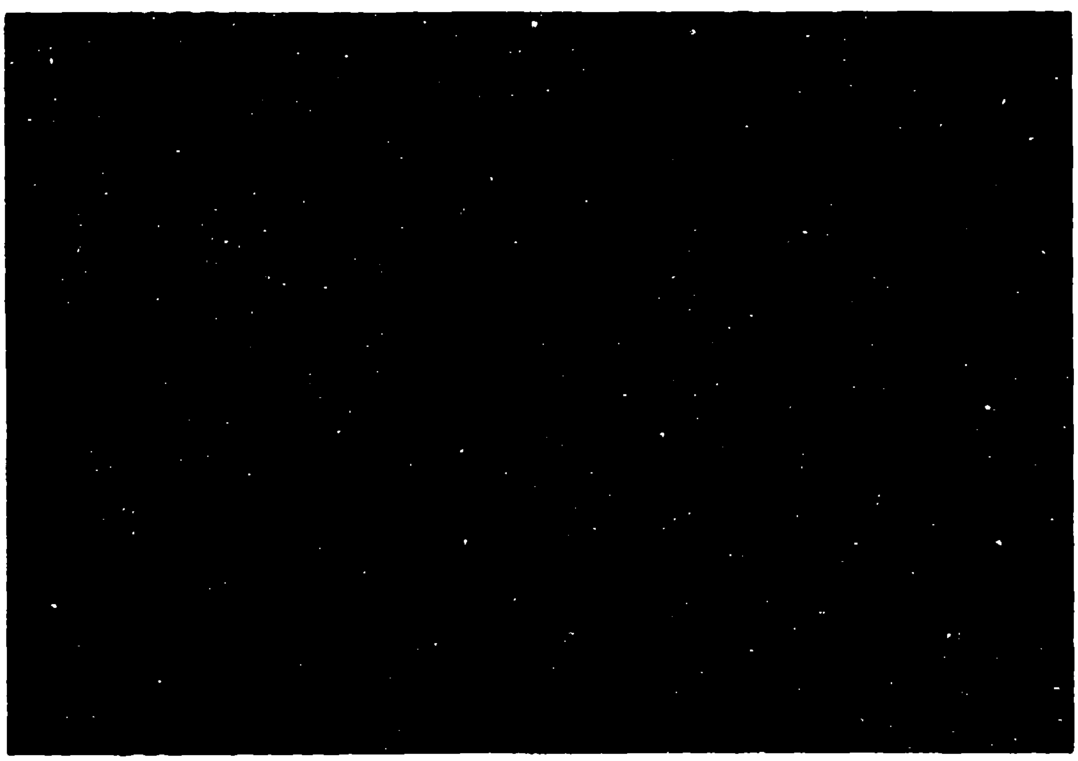

Figure 6. Older argon laser burns of the human retina.

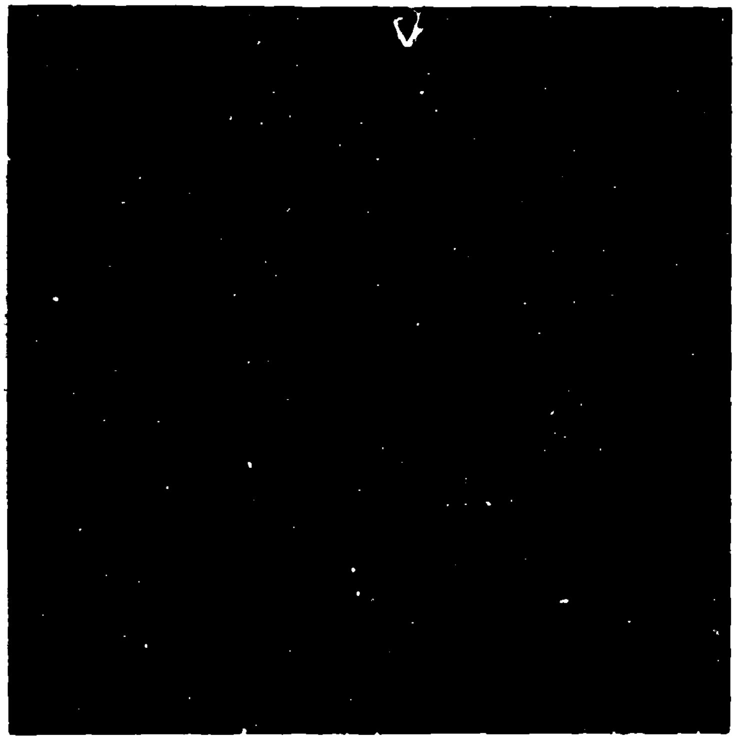

Figure 7. Acute Nd:YAG laser injuries to the monkey retina.

LASER EFFECTS ON VISION

Glare

Visible laser light can interfere with vision even at low energies which do not produce eye damage. Exposure to CW or rapidly pulsed, visible laser light can produce a glare, such as that produced by the sun, searchlights, or headlights. Glare can cause a reduction or total loss of target visibility, but these visual effects last only as long as the light is actually present in the individual's field of view. This will be most pronounced for objects nearest the glare source and results from light scatter caused by the atmosphere, other intervening transparencies, such as windscreens and visors, and the ocular media of the eye itself. Less laser light is required to totally obscure small, dim, or low-contrast targets. Because daytime scenes contain brighter objects than nighttime scenes, the same glare source will obscure more of the visual field at night.

Flashblindness and Afterimage

Visible laser light can also produce a lingering, yet temporary, visual loss associated with spatially localized aftereffects, similar to that produced by flashbulbs. Like glare, these aftereffects can occur at exposure levels which do not cause eye damage. One aftereffect, known as "flashblindness," is the inability to detect or resolve a visual target following exposure to a bright light. Flashblindness is due to the temporary depletion of visual pigments. Visual impairment from flashblindness may be operationally significant, especially if the visual field affected is large. However, this impairment is transitory, lasting seconds to minutes depending upon the laser's parameters, the visual task, the ambient lighting, and the brightness of the visual target. During flashblindness recovery, large bright targets will become visible before small dim targets. The diminished perception of cockpit displays caused by flashblindness may be overcome, to some extent, by turning the cockpit instrument lights to full intensity. While there is no permanent visual loss, a decrement in military performance during a critical, albeit short, time-frame may render the aircrew unable to accomplish the mission.

The other aftereffect, often confused with flashblindness, is "afterimage." Afterimages are the perception of light, dark, or colored spots after exposure to a bright light. Small afterimages, through which one can see, may persist for minutes, hours, or days. Afterimages are very dynamic and can change in color ("flight of color"), size, and intensity depending upon the background being viewed. It is difficult to correlate the colors of afterimages with specific laser wavelengths. Afterimages are often annoying and distracting but are unlikely to cause a visual decrement.

Visual Loss from Damage

The permanent damage caused by UV, visible, and IR lasers can cause variable degradations in vision, proportionate to the degree of damage. Corneal damage may significantly degrade vision due to increased light scatter from opacities or due to gross rupture. In addition, iritis (intraocular inflammation), seen in association with corneal injuries, may cause photophobia, pain, and miosis (small pupil). One must be cautious in ascribing a small pupil to a laser exposure, as asymmetric pupil diameters occur in approximately 25% of the population. Miosis can reduce night vision.

In the case of retinal damage, the severity of visual loss will depend upon the proximity and extent of the damage to the fovea. A graphic illustration of the potential Snellen visual

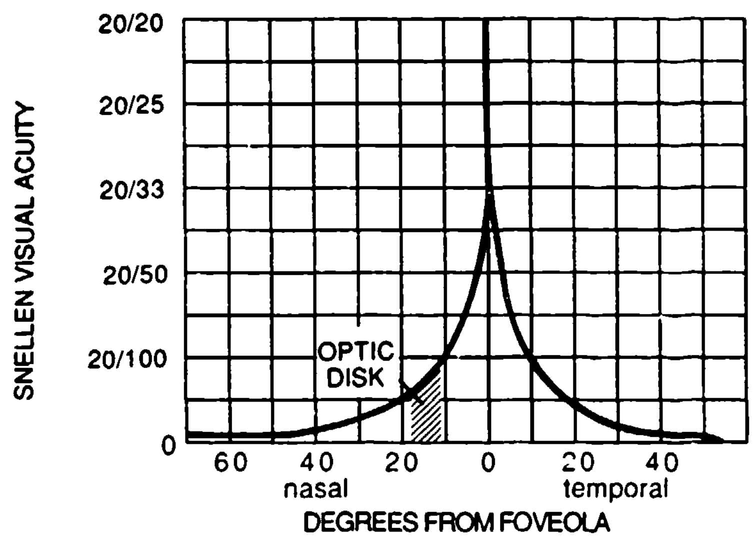

Figure 8. Acuity as a function of distance from the foveola. Acuity is greatest at the foveola and falls off sharply in the peripheral retina. The fall-off is relative to the maximal foveal acuity but has considerable individual variability. For illustrative purposes, this figure assumes that maximum visual acuity is 20/20 and relates the expected fall-off in vision to that maximum. (Adapted from Chapinis, 1949; data from Wertheim, 1894).

acuities of the human retina, for high-contrast targets, is presented in Figure 8. It shows that the best visual acuity occurs in the foveola/fovea, and that the acuity falls off sharply when moving toward the peripheral retina. Figure 9 depicts anatomically the posterior pole and the very small area (foveola) that subserves 20/20 vision. It illustrates the approximate visual capabilities of areas of the posterior pole. Obtaining those visual acuities requires placing the image of the object of regard on the undamaged retina. This process will likely require eccentric fixation and great concentration by the individual.

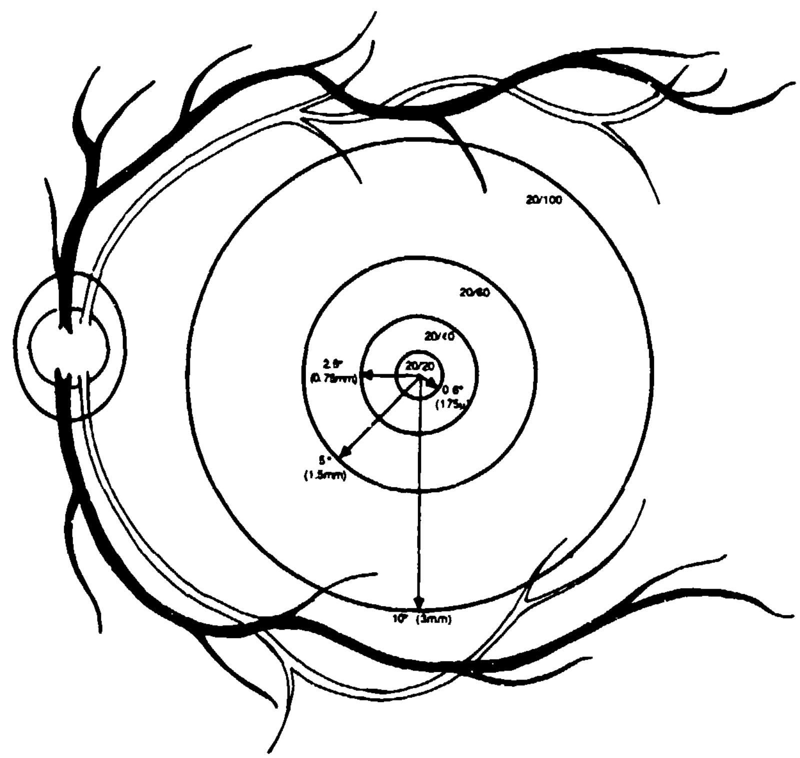

Figure 9. Map of acuity in the posterior pole. This map of the posterior pole shows the approximate relationship of visual acuity to the different retinal zones: 0.6-degree radius is the foveola; 2.5-degree radius is the fovea. Beyond a 10-degree diameter, visual acuity is worse than 20/100. (Adapted from Duane, 1987).

Functionally significant loss of vision usually occurs only if the burn directly affects the fovea. The expected minimum burn size (30-100 μm) for a low-power exposure to the fovea will have variable effects on visual acuity depending on location, with either no effect or a reduction in vision to approximately 20/40 for high-contrast targets. Figure 10 is an example of a minimal burn to the superotemporal fovea that did not reduce visual acuity. On the other hand, a direct laser burn to the foveola would definitely alter vision. An acute 200-μm argon laser burn directly in the human foveola can be seen in Figure 11. This photograph was taken within minutes after exposure. The vision was permanently reduced from 20/40 to 20/200. If the retinal damage includes hemorrhages, the visual loss may be more profound, as the blood may block the passage of light to uninjured portions of the retina.

Figure 10. Laser burn to the human fovea but peripheral to the foveola.

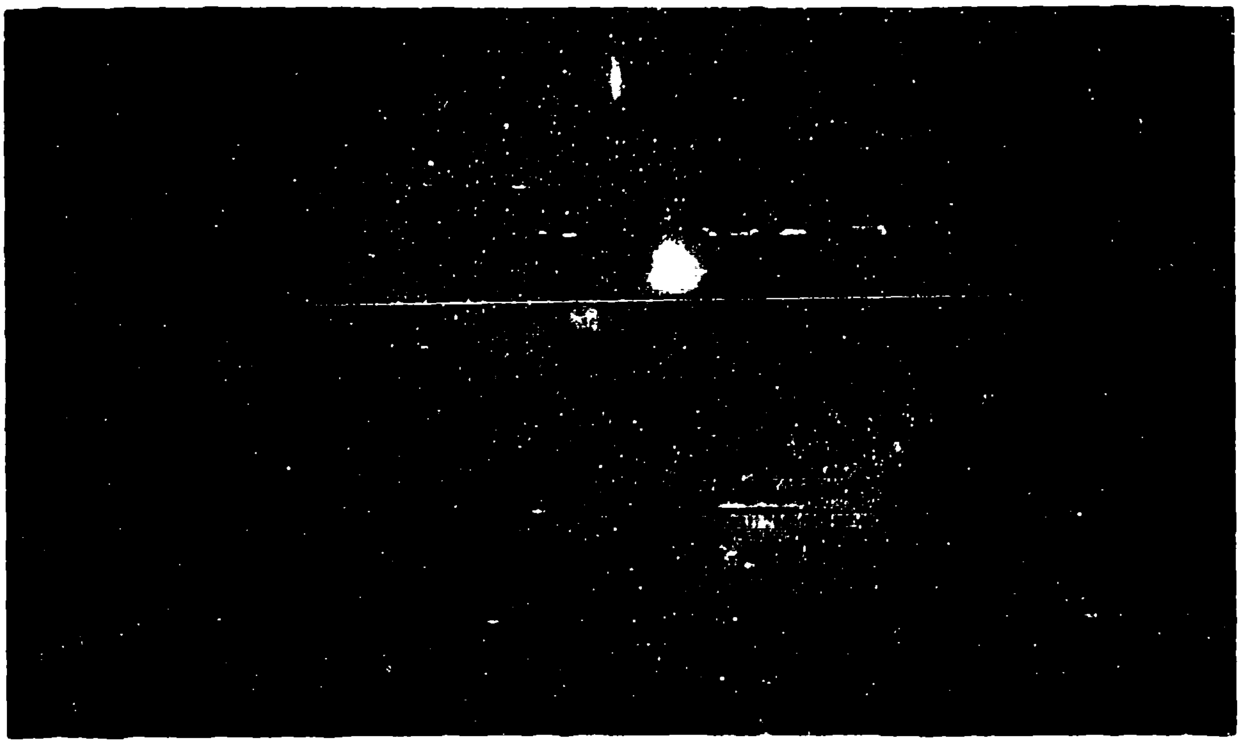

Figure 11. Acute argon laser burn to the human foveola.

In addition to visual acuity changes, damaged areas of the retina cause loss of visual perception in those areas of the visual field corresponding to the damaged portions of the retina. Large areas of peripheral visual field loss, while noticeable, may not be seriously handicapping, as central vision will not be affected. Such peripheral defects, if large, may be detected by confrontation tests.

On the other hand, central visual field defects caused by damage to the posterior pole will be noticeable and may be distracting or disabling, depending upon whether the foveola and thus visual acuity are affected. These central defects can be detected and characterized quite accurately with a simple test--the Amsler Grid. While annoying, small bilateral central visual field defects may not be seriously handicapping, if central visual acuity is unaffected. However, as shown in Figure 11, even a small (200 μm) laser burn directly to the foveola will cause a dense central scotoma (blind spot) and a severe decrement in visual acuity and performance.

A laser's light energy is likely to affect both eyes, unless one is occluded or otherwise protected, because the laser beam's diameter, at operationally significant distances, will be wider than the head.

SYMPTOMS

Symptoms will vary depending upon the location and severity of injury. Patients may give a history of experiencing glare, flashblindness, decreased vision, pain, or any combination. When seen by medical personnel, they may continue to complain of afterimages, blurred vision, photophobia, pain, or profound loss of vision. Reports by aircrew members of seeing bright flashes of light or of experiencing sudden or unexplained eye discomfort or poor vision should alert medical personnel to the possibility that they may be dealing with individuals injured by lasers. Obvious lesions, such as skin and corneal burns, and/or retinal burns and retinal hemorrhages make the diagnosis more certain, especially when accompanied by a history of seeing bright, colored lights. One must be careful with that history, however, because, at very high energy levels, colored visible light overwhelms the retinal photoreceptors and may be perceived as white. One may also be confused by injuries which are only irritations of the eyes and/or skin. In such cases, one needs to consider chemical injury. Spontaneous fires and unexplained damage to electro-optical instruments, such as night vision goggles (NVGs), are additional evidence that laser weapons may have been employed.

EXAMINATION

History

The information provided in previous sections, along with appropriate questions from "Medical Debriefing for Suspected Laser Incidents" (Appendix A), should all be used when questioning aircrews.

Routine Procedures

External Examination

The periocular tissue (lids and conjunctiva) and anterior segment (cornea, anterior chamber, and iris) of the eyes are evaluated on external examination. Laser injuries to the cornea will usually be limited to the area of the cornea within the palpebral fissure. Redness of the conjunctiva suggests ocular inflammation, possibly secondary to injury, that may be external or internal. A small pupil in the inflamed eye suggests, but does not confirm, the diagnosis of intraocular inflammation (iritis). The anterior chamber should be examined for blood.

Snellen Acuity

A "standard" eye chart (for distance or near) is used to measure visual resolution in each eye. The 20/20 characters on the chart have a letter height which projects an angle of 5 minutes of arc on the retina with 1 minute of arc features which, it is assumed, must be seen to correctly read the letters. This procedure tests foveal vision.

Confrontation Visual Fields

Finger-counting confrontation visual fields can be accomplished by the examiner facing the patient (at 1 m) and each closing the opposing eye. The examiner then extends his hands to the sides where he can see them with his open eye. He then flashes different numbers of fingers in each quadrant and elicits the patient's response. The same procedure is accomplished on the opposite eye. This procedure may help to identify gross peripheral visual field defects such as might be caused by a large hemorrhage, if the patient is unable to see the fingers of the examiner.

Amsler Grid

The Amsler Grid is a graph paper which, when held 30 cm (12 in) from the eye and viewed monocularly by the patient, can be used to plot areas of retinal injury or vitreous hemorrhage in the posterior pole (central 20 degrees). The Amsler Grid is sufficiently sensitive that it can detect lesions as small as 50 μm. Each eye should be tested separately. Figure 12 is a superimposition of an Amsler Grid on a drawing of the posterior pole to delineate the approximate area of the posterior pole tested by the Amsler Grid. The patient will report seeing visual distortion of the lines or a scotoma corresponding to the area of the posterior pole injured. The perceived visual field is upside-down and backwards to the corresponding retina, i.e., superotemporal retinal defects will be "seen" by the patient in his inferonasal field. The foveola corresponds to the central point of the visual field. Abnormalities in testing may indicate old stable conditions or new retinal/vitreal pathology. Bilateral abnormalities in the same areas of the visual field support the diagnosis of a laser eye injury. Figure 13 demonstrates laser scotomas due to bilateral, but unequal, foveal damage from a ruby rangefinder. See Appendix B for information on ordering Amsler Grids.

Stereopsis

An evaluation of stereopsis can be conducted by using the VTA-DP test or the AO vectograph (distance measurements), or the Verhoeff apparatus or Randot Titmus (near measurements). The results are a good estimate of binocular visual function, as well as a test of foveal vision, as each eye must usually be at least 20/25 for an individual to pass. Aviators should be tested with the VTA-DP (preferred test) or the Verhoeff apparatus.

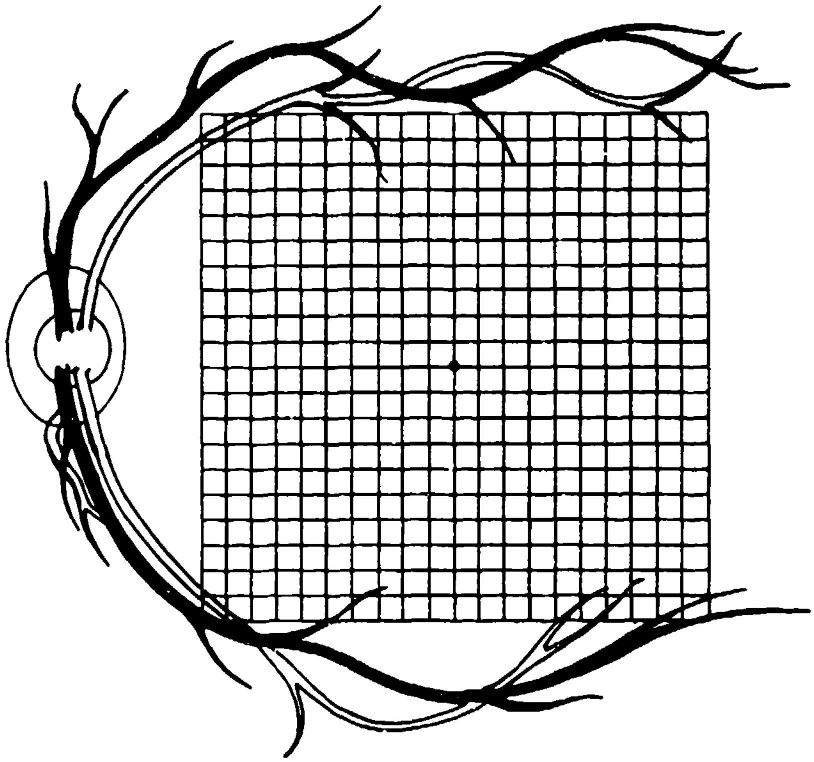

Figure 12. Area of the posterior pole tested by the Amsler Grid. (Adapted from Keeler (Hamblin) Ldt., Amsler Charts Report).

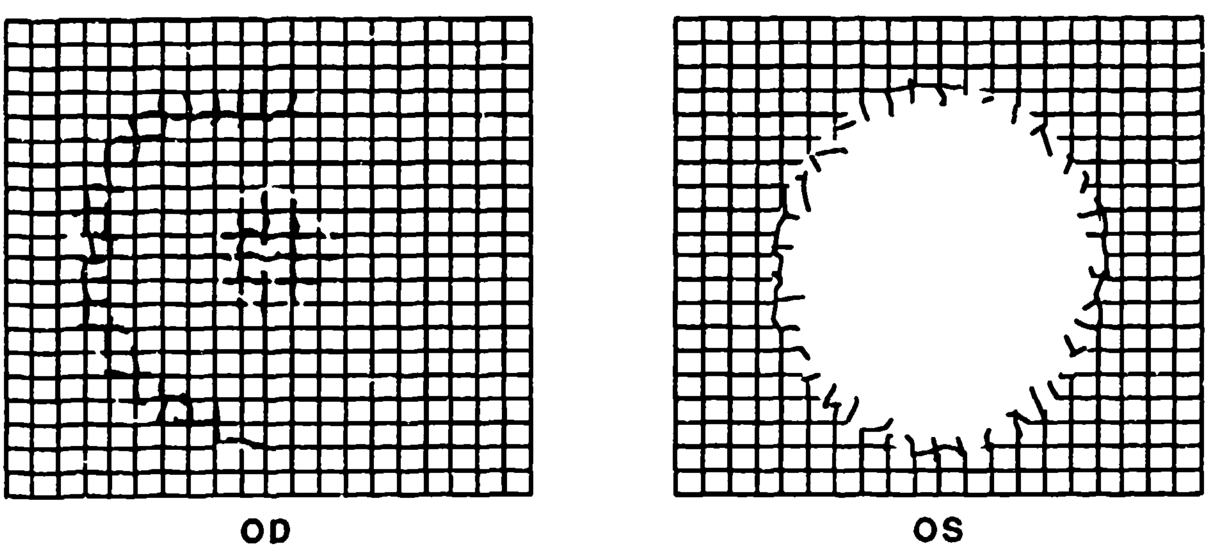

Figure 13. Amsler Grid abnormalities corresponding to foveal damage in both eyes. (Adapted from Lang et al., 1985).

Ophthalmoscopy

Using the direct ophthalmoscope, the examiner should be able to obtain a clear and undistorted view of the posterior pole in undamaged or mildly damaged eyes. Poor visualization of the posterior pole can result from corneal or lens opacities or a vitreal hemorrhage. Pharmacologic dilation may be used to facilitate this examination; this dilation may include Neo-Synephrine 2.5% alone (pupils dilated for 1 hour) or in combination with tropicamide 1% (pupils dilated for 4 to 6 hours). Both eyes should be examined.

Special Tests

Fluorescein Staining

Fluorescein staining of the cornea will be helpful in detecting corneal epithelial defects in patients complaining of an ocular foreign-body or "scratchy" sensation.

Color Vision

Pseudoisochromatic plates are a series of color vision test plates in which colored dots are arranged in the shape of a number or letter. The patient is asked to identify the number or letter. This test measures a function of the cone photoreceptors which are most numerous in the fovea centralis. If available, it may help in identifying a foveal injury. When used, it should be accomplished in each eye separately.

Tests for Malingering

The general types of malingerers include: individuals who deliberately feign a nonexistent visual loss; individuals who pretend that a condition is worse than it really is. Oddly, some individuals pretend that a disability does not exist. The reason malingerers feign disability is for secondary gain; they avoid a dangerous assignment or obtain a disability retirement.

In testing for total blindness (if monocular, you should cover the "good" eye), several simple objective tests can be done to demonstrate some vision:

1. Normal pupillary reflexes demonstrate the integrity of the lower visual pathways. This test is done before covering the "good" eye.

2. The Menace Reflex (quick avoiding blink) can be produced in normals by thrusting your hand toward the individual's eye(s).

3. The individual's ability to follow you rapidly through a crowded and disorderly room will give you clues regarding his "blindness."

4. Normally sighted and blind individuals can accurately complete proprioception tests, such as alternately touching forefingers to the tips of their noses and writing their names. Malingerers will try to "fail" these tests.

5. Malingerers feigning blindness will often smile or break into laughter, if you make faces at them.

6. The optokinetic nystagmus test (drum or tape) can rarely be suppressed. It is a test of reflex eye movements involving ocular pursuit of a moving stimulus.

7. If a mirror (at least 36 X 67 cm) is placed before the "blind" eye(s) and rocked, malingerers can often be "found out" because their seeing eye(s) follows the image in the mirror.

If you must demonstrate a specific level of vision, other more sophisticated tests may be used:

8. Stereoscopic tests (VTA-DP, Verhoeff, Randot Titmus, A-O Vectograph slide), if normal, suggest that the vision O.U. most probably is at least 20/25. "O.U." is the abbreviation for "Oculus Uterque," which means "each eye."

9. Surreptitiously blocking or fogging with "plus" lenses the vision in the "good" eye may enable you to demonstrate good vision in the "bad" eye.

10. Visual tests exist that require good vision in both eyes to read all the letters on the line, such as polarizing lenses with the Project-O-Chart slide and red/green lenses with the duochrome slide.

11. A 4-diopter or 6-diopter base-out prism, when placed quickly in front of the viewing "bad" eye, will cause a refixation shift and thus demonstrate that the eye was really fixating on the object of regard.

The mechanisms of these tests should never be explained to patients, especially ones suspected of malingering, as they may use that information to give invalid results on subsequent examinations.

PHYSICAL FINDINGS

No clinical findings may be apparent, if only subjective symptoms (glare, flashblindness, or afterimages) have occurred as the result of a non-damaging exposure, or if there is retinal damage or hemorrhage outside the fine vision area of the posterior pole. The latter may be asymptomatic and not seen with the direct ophthalmoscope. Malingerers will generally have either no objective findings, or symptoms out of proportion to objective findings.

Clinical findings due to damage may be variable and include the following: isolated, rows, or groups of retinal burns; retinal/vitreal hemorrhages; and superficial or deep burns of the skin and cornea.

1. Superficial burns of the cornea caused by UV light may not be visible without fluorescein staining.

2. Gross burns of the cornea will cause the cornea to become opaque and white.

3. Ruptured corneas should be apparent on external examination. The cornea will be seriously damaged. The anterior chamber will be shallow. The pupil may be eccentric and irregularly shaped. Iris tissue may be in or protruding through the corneal wound.

4. Conjunctival hyperemia and miosis suggest external and/or internal ocular inflammation that might possibly be due to laser injury of the cornea.

5. Retinal burns initially appear white due to coagulation and edema, but usually develop some pigmentation (blackness) over days to weeks.

6. Retinal disruption may appear without overlying hemorrhage, but this is unlikely due to the energy applied. If disruption does appear alone, the retina will look in disarray, and the bright-red choroid beneath it will be visible.

7. Even severe retinal damage may be hard to visualize, if there is blood in the vitreous.

TREATMENT

Corneal Injuries

The treatment for corneal burns is the same as for burns of other etiologies, namely, the use of antibiotic coverage and eye dressings. The principles regarding facial burns, smoke inhalation, and airway maintenance must be followed. Patch only the eye with the injured cornea. Any associated iritis and its attendant pain can be treated with pupillary dilation using cyclogel 1%, one drop in the affected eye(s) every 8 to 12 hours. If the eye has been ruptured, the likelihood of saving it is low; do not use regular eye patches for such injuries, as these put pressure on the eye. Rather, the eye should be protected by a metal eye (Foxx) shield from any external pressure. Do not put any eye drops or ointments on a ruptured eye. The patient should be kept physically quiet in a supine position. In addition, the patient should be started on intravenous antibiotics, if possible. Priority of evacuation depends on the severity of injury and the likelihood of saving the eye. Pain medication may be required for patient comfort. Topical anesthetics should never be given to the patient, but they may be used by the physician to aid in the examination and treatment of nonruptured globes.

Retinal Injuries

At present, the treatment for laser injuries to the retina/choroid is not well-defined. Ocular and oral corticosteroids have not been proven effective for the treatment of retinal burns or hemorrhages. The use of eye patches for retinal damage is discouraged. Patching deprives the patient of his residual vision which may be quite good. It also has the effect of magnifying the visual impairment to the aircrew member and increasing his dependence on others. Personnel with vitreal hemorrhages should be maintained at bed rest with their heads positioned so that the blood settles away from the visual axis, particularly for the first few days. Delayed or tertiary treatment of vitreous hemorrhage consists of vitrectomy and associated procedures, but only for those eyes that do not have adequate spontaneous absorption of the blood. Patients with retinal damage currently have a low evacuation priority.

NOTE:

Any suspected laser injury should be reported to medical care providers and command headquarters.

RETURN-TO-DUTY CRITERIA

An assessment of visual function and other findings, such as pain, should be made to determine how effective each individual will be to his unit. In general, if no extensive external ocular damage, pain, or threat of ocular complication exists, the visual acuities listed in AFR 160-43 serve as a guide. Personnel with best corrected visual acuities of at least 20/40 in the better eye and no worse than 20/400 in the other are returnable to duty. The specific duty they perform will be determined by the unit and the medical officer. Reevaluations may be conducted based upon worsening vision or other symptoms.

Aviators whose vision has been affected by a laser may remain at the front, but whether or not they perform aviation duties will be determined by the degree of vision loss, the extent of central visual field loss, whether the condition(s) is bilateral, the duties they are required to perform in the air, and the intensity of the engagement. Aviators with either large contained retinal or vitreous hemorrhages should not fly, as the blood may shift and occlude the visual axis. For the elective return of pilots to flight duty, the following short chart can serve as a general guide:

Best Visual Acuity		Amsler Grid	Stereopsis	Mission
Better eye	Worse eye			
20/20	20/30	Abnl one eye	Normal	All missions
20/25	20/30	Abnl O.U.	Normal	Air to ground or transport
20/30	20/40	Abnl O.U.	Abnormal	Emergency evacuation of aircraft in daylight

Other combinations of visual acuities are possible. The flight surgeon must use his best judgment, understanding the flying demands, in returning individuals with eye damage to flying duties. Aviators with 20/40 vision in their better eye should probably not be returned to flying duties. Bilateral foveal injuries, in spite of reasonable visual acuity, can cause a loss of confidence in a pilot with previously excellent vision.

EVACUATION CRITERIA

Personnel with best corrected vision worse than 20/40 in the better eye can be removed from duty and considered for evacuation. The capability of medical evacuation and the intensity of the engagement will determine whether these casualties will be evacuated or remain. Remember, soon after the injury, the vision may be poor, but it may improve over several days.

Ophthalmologists will normally be available at the fourth echelon of medical care, and in rare instances the third, for consultation and to accept patients who require further evaluation and care. Optometrists may be available at the second echelon of medical care but will usually be on the staff at the third. Optometrists can aid flight surgeons and other medical officers in the examination and diagnosis of ocular conditions.

PREVENTION AND PROTECTION

Narrow-band eye goggles and visor filters that block laser energy at specific wavelengths are the best form of protection. The ideal protector would filter only the threat wavelengths and allow others to pass. The use of such selective filters may result in a perceived alteration of colors in the scene being viewed.

The level of protection for laser eyewear is defined in terms of optical density (OD) at each wavelength. The higher the OD, the greater the protection. The OD refers to the amount of light energy striking the laser eyewear that is allowed to pass through to the eye. An OD of 1 reduces the incident light by a factor of ten, an OD of 3 by a factor of 1,000, and an OD of 5 by a factor of 100,000. This is calculated using the formula:

$$OD = \log_{10} \frac{1}{\text{Transmittance}}.$$

In addition, canopies, windscreens, or other plastics provide protection to the eyes of aircrew members from the effects of low-power ultraviolet and far-infrared lasers. Sunglasses and ordinary spectacle lenses may also offer some protection from the effects of low-power ultraviolet and far-infrared lasers, but they are definitely not as effective as specially designed laser eyewear and are not recommended for primary laser protection. A pair of standard USAF sunglasses (15% transmission) has an OD of only 0.8 across the visible spectrum.

The amount of laser light energy reaching the eye itself depends upon the OD of the protective filter, the emitted power and wavelength(s) of the laser, the distance of the eye from the laser, and certain other variable factors, such as atmospheric conditions (clouds, dust, smoke, rain), which can attenuate the laser light. Even when proper laser eye protection is in place, one may still be able to see the laser light source. Normally this laser light will not cause damage.

Many techniques and eyewear can help to protect the eye:

1. Use laser-protective goggles/visors specifically designed for the threat wavelengths.

2. Go "heads-down" in the cockpit. Take cover if on the ground.

3. Avoid looking directly at light sources.

4. Maneuver the aircraft to obstruct the laser beam's illumination of the cockpit.

5. Use your hand to shield your eyes.

6. Make use of billowing smoke, clouds, or fog, as they scatter laser energy.

7. Close one eye.

8. Use sunglasses or sun visors, if nothing else is available. They will reduce all incident light somewhat.

9. Minimize the use of binoculars and sighting devices or other direct-view optical devices.

10. Use hardened (block harmful laser light) optical systems.

11. Cover skin with clothing to prevent skin burns.

12. Use countermeasures, as taught or directed.

PSYCHOLOGICAL IMPACT

The use of laser weapons has the potential for having a very significant psychological impact on aircrew. Much of this impact can be alleviated by proper and well-directed education efforts. Some laser effects are only temporary and noninjurious. Acute visual loss due to laser injury may improve with time, and injured personnel should be given that hope. In addition, they should be reassured that it is unlikely that they will lose all vision and be "blind." The chief source of expert knowledge and education for commanders and their aircrew members will be medical personnel, particularly flight surgeons, ophthalmologists, and optometrists. The flight surgeon should actively participate in education sessions designed to teach the aircrews about lasers, their effects, and methods of self-protection.

A laser attack has the potential for occurring as a total surprise. Steps must be taken <u>before</u> engagement to alleviate fears of "death ray" lasers and helplessness in the air or on the battlefield due to loss of vision. Use of protective goggles and visors <u>must</u> be emphasized, and aircrews should be <u>reassured</u> that the use of appropriate devices will protect their eyes.

BIBLIOGRAPHY

1. AFOSH Standard 161-10, Health control for laser radiation, 1980.

2. American National Standard for the Safe Use of Lasers (ANSI Z136.1-1986). The Laser Institute of America, Toledo, 1986.

3. Amsler charts manual, orig. by Hamblin (Instruments) Limited, London, England, now part of Keeler (Hamblin) Limited, Broomall PA, London, England.

4. Boff, K. R., L. Kaufman, and J. P. Thomas (Eds.). Handbook of perception and human performance. Vol 1: Sensory Processes and Perception. John Wiley and Sons, New York, 1986.

5. Chapinis, A. How we see: a summary of basic principles. Human factors in undersea warfare. National Research Council, Washington, D.C., 1949.

6. Constable, I. J., and A. Lim. Laser, its clinical uses in eye disease. Churchill Livingstone, Edinburgh, 1981.

7. Duane, T. D. (Ed.). Clinical ophthalmology. Harper and Row Publishers, Philadelphia, 1987.

8. Lang, G. K., G. Lang, and G. O. H. Naumann. Akzidentelle bilaterale asymmetrische Rubin-Laser-Makulopathie. Klinische Monatsblatter fuer Augenheilkunde, Vol 186, No 5, May 1985, pp. 366-370. Translation available.

9. L'Esperance, F. A., Jr. Ocular photocoagulation: A stereoscopic atlas. C.V. Mosby Company, St Louis, 1977.

10. McKinley, R. W. (Ed.). IES lighting handbook. Illuminating Engineering Society. New York, 1947.

11. Ophthalmology Basic and Clinical Science Course, American Academy of Ophthalmology, San Francisco, 1983.

12. Orth, D. H., et al. Clarification of foveomacular nomenclature and grid for quantification of macular disorders. Ophthalmology Transactions: American Academy of Ophthalmology and Otolaryngology, Vol 83, 1977.

13. Sliney, D., and M. Wolbarsht. Safety with lasers and other optical sources: A comprehensive handbook. Plenum Press, New York, 1980.

14. Steinert, R. F., and C. A. Puliafito. The Nd:YAG laser in ophthalmology: Principles and clinical applications of photodisruption. W.B. Saunders Company, Philadelphia, 1985.

15. Trokel, S. L. (Ed.). YAG laser ophthalmic microsurgery. Appleton- Century-Crofts Publishers, E. Norwalk, Connecticut, 1983.

16. Wertheim, T. Uber die indirekte Schscharfe. Z Psychol, Vol 7, 1894, pp. 172-187.

17. Wyszecki, G., and W. S. Stiles. Color science: Concept and methods, quantitative data formulae. John Wiley and Sons, New York, 1982.

APPENDIX A

MEDICAL DEBRIEFING FOR SUSPECTED LASER INCIDENTS

CIRCUMSTANCES

1. Did you see a bright light? How bright was it, like the sun, a full moon, or automobile headlights at night? Were their other light sources on the platform (such as running lights or navigation lights) and were they brighter or dimmer?

2. What was the color(s) of the light? Was it uniform in color? Did the color(s) change during the exposure?

3. Did the light come on suddenly, and did it become brighter as you approached it?

4. Was the light continuous or did it seem to flicker? If it flickered, how rapidly and regularly?

5. For how long was the light on?

6. From what did the light emanate? Was it from an airplane, helicopter, tank, etc.?

7. How would you describe the brightness of the light? Was it equally bright in all areas or was it brighter in one area?

8. How far away was the light source? Was it moving?

9. At what time of the day did the incident occur?

10. What was the visibility? What were the atmospheric conditions - clear, overcast, rainy, foggy, hazy, sunny?

11. What was between the light source and your eyes - windscreen, glasses, head-up display, lenses, binoculars, filters, visors, or goggles? Describe them in great detail (for example, 2X binoculars, standard issue sun visor, prescription glasses, hazy windscreen). Were any of these things damaged or caused to malfunction by the light?

12. Did you try to move out of the light beam? What evasive maneuvers did you attempt? Did the beam follow you as you tried to move away? How successful were you in avoiding it?

13. Was the light coming directly from its source or did it appear to be reflected off other surfaces? Did you notice multiple sources of light?

14. Did the light fill your cockpit or compartment? How wide was the beam at its source? How wide was the beam once it reached you?

POSSIBLE EFFECTS

15. How long did you look into the light beam? Did you look straight into the light beam or off to the side?

16. What tasks were you doing when the exposure occurred? Did the light prevent or hamper you from doing those tasks, or was the light more of an annoyance?

17. Were both eyes exposed? If not, describe the difference between the light exposures (for example, one eye was shielded or closed, or on the side away from the light beam). Describe any difference in the effects on either eye.

18. Were you startled or disoriented when the light appeared?

19. Was the light so bright that you had to blink or squint, close your eyes, or look away? Was the light painful? Describe the pain. For how long did the pain persist after the light exposure?

20. Was your vision affected while the light was on? How much of your visual field was affected? What types of things could you see or not see? Did you notice the color of instruments or targets change? Did the changes to your vision remain constant or vary during the exposure? If the light source was mounted on a platform (aircraft, ground vehicle or building), how much of the platform was obscured? [Note: Recommend that the word "dazzle" not be used because its definition varies greatly; "glare" is the preferred word.]

21. Did your vision remain affected after the light was extinguished? If so, for how long and how did you estimate the time? How much of your visual field was affected? What types of things could you see or not see (watch, hand, altimeter, map, etc.)? Did you notice afterimages ("spots before your eyes")? If so, how long did they last, what did they look like, and what were their size, shape and position in your visual field? Describe how your vision was affected 10 seconds after the light exposure ended, 30 seconds afterwards, 1 minute, 2 minutes, etc?

22. Were there any lingering (hours or days) visual effects? If so, were the effects continuous or intermittent? Did you have problems reading or seeing in low-light conditions? How long until you were able to see normally again?

23. Did you notice any reddening, warming, or burns to your skin?

24. Describe the condition of your vision before the incident? Do you wear glasses? Are you taking any medications?

25. Did you seek medical attention following the incident? Where and when were you examined? Who performed the examination? Was the examiner an ophthalmologist or optometrist? What were the clinical findings?

APPENDIX B

INFORMATION FOR ORDERING AMSLER GRIDS AND VIDEOTAPE

1. Small Amsler Grids, which are encased in plastic and have near visual acuity testing lines on the opposite side, can be purchased directly from:

> Bernell Corporation
> 750 Lincolnway East
> P.O. Box 4637
> South Bend, IN 46634
> 1-800-348-2225

After about 1990, the Amsler Grids should be a government stocklisted item.

2. A videotape, produced jointly by the United States Air Force and United States Navy, is available from the base audiovisual library or HQ/AAVS, Norton AFB CA 92409.

> "Lasers in Military Operations, Part I" (803562DN)
> Subj: Laser Physics/Bioeffects/Eye protection

Other videotapes about laser systems and human effects are also available from the base audiovisual library or HQ/AAVS, Norton AFB CA 92409.

END

FILMED

DATE: 4-91

DTIC